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ABSTRACT

Designed to address conceptual problems associated with ecology, this module can be used with high school students or college nonscience majors including those in elementary education. The materials offer guidance to teachers in diagnosing student deficiencies, in creating dissatisfaction with misconceptions, and in providing opportunities for application and practice. This module contains: (1) an introductory section (discussing the misconceptions related to the understanding of ecology and how to use the module to overcome these barriers); (2) diagnostic test and commentary (designed to be used as a pretest and/or posttest); (3) materials for lecture or discussion (consisting of a series of copy-ready masters for use as overhead transparencies and student handouts on the topics of matter and energy, energy flows and matter cycles, food webs and trophic levels, food and energy pyramids, carbon and nitrogen cycles, and succession); (4) field activity (providing guidelines and suggestions for a field trip on succession); and (5) problem sets and commentary (presenting problems associated with energy flow, matter cycles, succession, and habitats and niches). (ML)

Occasional Paper No. 94

ECOLOGY: A TEACHING MODULE

Shirley Brehm, Charles W. Anderson,
and Joann DuBay

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Abstract

This module is one in a series developed by the project Overcoming Critical Barriers to Learning in Nonmajors' Science Courses. Each module is self-contained and addresses a specific topic in the physical and biological sciences: respiration and photosynthesis, evolution by natural selection, light, heat and temperature, and ecology. The modules are appropriate for use with high school students or college nonscience majors including those in elementary education.

This module on ecology is arranged with materials for the instructor on one page juxtaposed by those for the students. A short introductory essay describes the major conceptual problems found among students: difficulties with basic physical concepts, ecological structures and processes, and ecological succession. It then explains how activities in the unit are intended to help students overcome these problems.

A diagnostic test, which could be used as a pretest, posttest, or both, is designed to reveal important student misconceptions and provides notes for the instructor to interpret student responses. A set of student handouts and masters for overhead transparencies includes notes for the instructor about conceptual problems each was designed to address. A field trip on succession is followed by problem sets on (a) energy flow, matter cycling, and succession and (b) habitats and niches designed to address specific student misconceptions.

The first three parts can be used independently or in combination with the laboratory activities and problem sets after students have learned the relevant concepts. The materials help instructors accomplish three tasks essential to overcoming critical barriers to student learning: diagnosing student deficiencies, creating dissatisfaction with misconceptions, and providing opportunity for application and practice.

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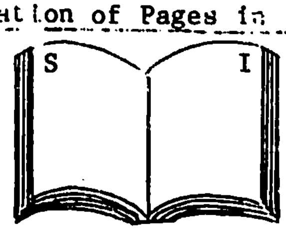
Table of Contents

		Page
	Preface	iv
I.	Introduction. *Read this first.* It contains information essential to understanding the nature and purposes of this module	1
	Understanding Ecology	1
	Structure of an Ecosystem	1
	Matter Cycling	1
	Energy Flow	1
	Succession	2
	Critical Barriers to Understanding Ecology	2
	Difficulties with Basic Physical Concepts	3
	Difficulties with Ecological Structures and Processes	3
	Ecological Succession	5
	Summary	
	Using this Module to Overcome Critical Barriers	7
II.	Diagnostic Test and Commentary	9
III.	Materials for Lecture or Discussion with Commentary	13
	Matter and Energy (overhead transparency)	14
	Energy Flows and Matter Cycles (overhead transparency)	15
	Food Webs and Trophic Levels (overhead transparency)	16
	Food and Energy Pyramids (overhead transparency)	17
	Carbon Cycle and Nitrogen Cycle (overhead transparency)	18
	Succession in Mid-Michigan (overhead transparency)	19
IV.	Field Activity: Succession Field Trip	20
V.	Problem Sets and Commentary	22
	Problem Set 1: Energy Flow, Matter Cycles and Succession	23
	Problem Set 2: Habitats and Niches	25

Organization of Pages in this Module



Student Pages — Instructor Pages

Pages with instructional materials to be used by the students are on the left side.

Pages with information for instructors are on the right side.

Preface

We hope that using this module will help you gain insight into your students' understanding, and misunderstanding, of ecology. One of its main purposes is to provide opportunities for you to learn about your students' thinking. Because of what you discover about their thinking, you may have to move more slowly and cover less content than you would like. That may seem like a problem, but we don't think so. It is far better to have students learn to understand a little science than to have them misunderstand a lot.

I. Introduction

Understanding Ecology

When can you be satisfied that your students "understand" ecology at some basic, minimal level? This is a question that all teachers of beginning or nonmajors' science courses must ask themselves. There is a great deal that students in these courses don't know, and a teacher can teach only what is most basic and essential for the development of further understanding.

In developing this module, we have assumed that ecology is, first and foremost, the study of *systems* containing a multitude of different organisms. Rather than focusing on individual organisms, an ecological perspective focuses on structures and processes which include a variety of interacting organisms. The analogy with the study of individual multicellular organisms is instructive: Anatomy is the study of tissues and organs made up of many individual cells, and physiology is the study of processes involving many cells.

What, then, are the "anatomical structures" and "physiological processes" of an ecosystem? There are many such structures and processes. In this module we develop a simple structure for ecosystem and emphasize these processes that take place within that structure: matter cycling, energy flow, and succession.

Structure of an ecosystem. Every ecosystem can be divided into an abiotic environment and a living community. The living community can in turn be subdivided into autotrophic producers, heterotrophic consumers, and heterotrophic decomposers; the consumers can be subdivided into herbivores and carnivores; and so forth. Ultimately a separate ecological niche and habitat can be specified for each population in the community. The major structures of an ecosystem generally cannot be identified with a particular physical location like organs in the human body. The parts of an ecosystem interpenetrate one another physically; they are separated not by their locations but by their places in the processes of the ecosystem. The most important of those processes are matter cycling and energy flow.

Matter cycling. Matter cycles endlessly within the biosphere. Water, carbon dioxide, and inorganic minerals are taken up by autotrophs and their atoms are recombined into complex organic molecules. Those molecules are passed from one organism to another through food chains until eventually the molecules are broken down through metabolic processes or death and decay. The atoms, though, are never destroyed. They are reincorporated into water, carbon dioxide, and inorganic minerals and are available for another cycles. One major theme in ecology is the study of the biogeochemical cycles by which various elements move from the abiotic environment, through the living community, and back again. In this module we focus primarily on the most basic of these biogeochemical cycles, the carbon cycle.

Energy flow. In order for ecosystems to continue functioning, a constant supply of energy is necessary. Energy and matter are alike in that both are subject to conservation laws in biological systems: Neither is ever created or destroyed. Unlike matter, though, energy can never be recycled. It enters almost all ecosystems in the form of sunlight and is converted to chemical

potential energy in organic molecules through the process of photosynthesis. That chemical potential energy is then passed from one organism to another through food chains. It ultimately leaves the ecosystem as heat when those organic molecules are broken down. Since every organism must convert some chemical potential energy into heat, there is an "energy pyramid," with less energy available to organisms at higher trophic levels. In this module we focus on developing an understanding of how energy flow in ecosystems is related to, and how it is different from, matter cycling.

Succession. A complex mature ecosystem does not spring into life fully developed. Rather, it develops through stages in which the biotic community generally becomes larger, more complex, and more diversified. The study of succession is comparable to the study of embryology in individual organisms; in each case complex mature systems and processes emerge from simple beginnings.

This module is designed to develop in beginning biology students a basic understanding of the four conceptual schemes described above. We have found that a meaningful understanding of these concepts is absent in most of our students, even those who have had previous biology courses. There are critical barriers to understanding that make these concepts very difficult for most students.

Critical Barriers to Understanding Ecology

This module is based in part on our own experience in teaching and developing materials for a college nonmajors' biology course. It is also based in part on a psychological theory that has been developed through extensive research comparing inexperienced students with scientific experts as both deal with scientific problems. In general, this research shows that the students think and act in ways that make sense to them, but that are incompatible with scientific thought. For example, many students have trouble learning about photosynthesis because they assume that plants, like us, must somehow take in food from the environment.

The presence of these alternate ways of thinking makes the learning of science a far more complicated process than scientists normally imagine. Students cannot simply absorb or memorize scientific content. They must reassess and restructure their intuitive knowledge of the world. Furthermore, they must abandon misconceptions or habits of thought that have served them well all their lives in favor of new and unfamiliar ideas.

The old habits of thought can be amazingly resistant to change through instruction. They persist even after students have apparently learned the scientific alternatives. Many students become quite good at learning what is expected of them to pass science tests while continuing to use their old ideas in "real world" situations. We have adopted a phrase from David Hawkins and describe these enduring habits of thought that interfere with scientific thinking as "critical barriers" to the learning of science. Hawkins defines these as "irretrievably elementary stumbling blocks" that prevent students from fully understanding scientific concepts and principles. This module is the product of a research and development project in which we have tried to

understand the critical barriers to student learning in a nonmajors' biology course, then to design materials and activities that will help students overcome those barriers.

Beginning biology students usually have several important misconceptions or habits of thought that act as critical barriers to their understanding of ecology. Some of the barriers that we have found are described below.

<u>Difficulties with basic physical concepts</u>. An understanding of matter cycling and energy flow in ecosystems clearly depends on students having some understanding of the nature of matter and energy. Unfortunately, we have found that these are very difficult concepts for many of the students in our courses, most of whom have never taken a course in chemistry or physics. Many students have trouble with the chemical concepts on which a scientific understanding of matter cycling is based. They are often unsure exactly what atoms and molecules are, for instance, or how they are combined to make objects and organisms in the world. They are unfamiliar with the distinctions between physical and chemical changes or between organic and inorganic compounds. Chemical formulas, even simple ones like O_2 and CO_2, are not meaningful to most of our students. They cannot, for instance, draw a picture to show what a gas consisting of a mixture of O_2 and CO_2 would look like on a molecular level.

Energy-related concepts cause similar difficulties for many of our students. Most of our students can successfully identify heat, light, and chemical potential energy as forms of energy. However, many students also mistakenly identify one or more of the following as energy:

1. Unrelated concepts such as temperature or force,

2. Energy-rich forms of matter such as food or organic materials, and

3. Energy conversion processes such as photosynthesis and respiration.

For students with these difficulties, tracing energy flow through ecosystems can obviously be a difficult process.

We do not attempt to resolve these difficulties in this module. Instead, we rely primarily on modes of explanation that do not assume a deeper understanding of matter and energy than most of our students possess. There are other modules in this series, especially those on *heat* and *respiration* and *photosynthesis*, which are designed to improve students' understanding of concepts related to matter and energy.

<u>Difficulties with ecological structures and processes</u>. We have found that, instead of viewing ecosystems as organized wholes, our students tend to see a living community primarily as a collection of individual organisms. They are unaware of, or are unable to use, the organizing principles that biologists use to understand ecological systems and processes.

Students generally know quite a few facts about interspecific interactions and interactions between organisms and the abiotic environment,

especially if those interactions involve only one or two species. They are aware that organisms need oxygen, water, and other substances from the environment. They can also describe a variety of relationships between two species, including symbiosis, parasitism, and predation.

When we have investigated our students' understanding of larger structures and processes, those involving many different populations or the ecosystem as a whole, we have found our students to be much less knowledgeable. Most do know of the existence of food chains, and many (not all) can answer questions requiring them to construct food chains containing more than two species. They can, for example, explain why wolves require green plants to survive. Most of our students can also distinguish between producers and consumers and between herbivores and carnivores. But there are many other important ecological structures and processes which our students understand little or not at all. Several of these are listed below:

1. The role of decomposers in ecosystems. Although our students understand food chains involving producers and consumers, most exhibit little awareness of decomposers or understanding of the role that they play in an ecosystem. Most students felt that it would not be good if all the bacteria and fungi were removed from an ecosystem, but they were not sure why it would be harmful. Only a few mentioned recycling or any equivalent idea.

For example, consider the following answers to diagnostic question 2 (see page 10 of this module), which asks what would happen in an ecosystem without bacteria and fungi:

> 1. "Certain trees and plants would die [because] bacteria would no longer be present as a food source."
>
> 2. [There would be] "lots of foliage [because] no bacteria would eat it."
>
> 3. "I'm not exactly sure. Bacteria and fungi are vital in chemical reactions, etc. I assume this could destroy or really upset the ecosystem's balance."

2. Matter cycling. Given their lack of awareness of decomposers and their role in the ecosystem, it is not surprising that most students' awareness of matter cycling is limited to that portion of the cycle which occurs in food chains. They are aware that individual organisms take in and release various substances, and that they are sometimes eaten. They do not see those processes, however, as playing a role in any larger cyclical ecological process. Their awareness of matter cycles involving specific chemical elements, such as the carbon cycle or the nitrogen cycle, is further inhibited by their difficulties with chemical concepts.

3. Energy flow. Consider the following answers to diagnostic question 4 (see page 11), which asks students to select a human food and trace the energy in the food back to its ultimate source:

Question	Student 1	Student 2
Humans get energy from	"H_2O"	"milk"
What energy comes from	"hydrogen and oxygen"	"a cow"
which comes from	"air"	"grass the cow eats
which comes from	"molecules"	"water, photosynthesis, dirt"

Like the students who wrote the above answers, many of our students aren't quite sure what is energy and what isn't. They find it very hard to trace the flow of energy through biological systems. They also find it hard to understand why biologists would find tracing energy flow a useful thing to do. Finally, they often have difficulties making conceptual distinctions which depend on an understanding of energy. Why, for instance, is it so important to distinguish between organic and inorganic compounds? Why do we consider food chains to start with producers rather than with the materials that producers take in? Shouldn't "plant food" have a place in a food chain? These questions are difficult ones for our students because energy, especially chemical potential energy, plays an important role in their answers.

4. Energy pyramids. Without a clear concept of energy flow, most students also fail to comprehend the idea of an energy pyramid: Because some chemical potential energy is used for metabolism at each trophic level, production is less at higher trophic levels. Therefore biomass and population size also tend to be less at higher trophic levels. Very few of our students use these ideas in reasoning about ecosystems. For instance, less than 15% correctly predict that the deer population should be much larger than the wolf population on an imaginary island (question 1, page 10). Many of the other students base their reasoning on a misinterpretation of what they have heard about the "balance of nature," reasoning that "balanced" populations of predator and prey should be close to the same size. Still other students reason about adaptive characteristics of wolves and deer:

> [The wolf population would be larger because] "wolves would kill the deer to eat."

> [The wolf population would be larger because] "wolves produce more offspring at a faster rate."

<u>Ecological succession</u>. The last question on our diagnostic test (page 12) asked students to predict what would happen to a cornfield in central Michigan which is left fallow for 100 years. The types of answers that our students gave to the question are summarized in Table 1, page 6. A few students seemed to believe that without continued human intervention no life could be maintained on the field at all. More common were answers in which the description of succession ended with weedy overgrowth. Even those students who correctly predicted that trees would eventually grow (the climax community in this area is a beech-maple forest) showed little awareness of successional trends which ecologists consider important, such as trends toward greater species diversity, greater population stability, more effective nutrient recycling, and so forth.

Table 1

Student Conceptions of Succession

Issue	Goal Conception	Naive Conception
The nature of succession	Emphasizes development of diverse and interdependent communities of plants and animal life in a specific geographic setting.	1. An arrested succession ending in weeds 2. A negative succession arriving at bare soil or decay
Trends in soil fertility	Soil becomes fertile as decomposers break down organic matter in soil	1. Soil fertility attributed to decay 2. Soil is fertile only if humans intervene 3. Soil trend toward decreasing fertility (soil, is infertile, barren)
Trends in plant community	A natural process in which a perceivable order of plants will develop in succession leading toward a diverse forest community in dynamic equilibrium	1. Bigger & bigger plants as time goes by 2. Arrested succession ending in weeds 3. Negative succession--plants die out
Trends in animal community	A succession of animal populations, each associated with a particular plant community; general trend toward larger animal size and more stable populations.	1. Bigger animals--bigger plants 2. Arrested succession ending in insects and small animals 3. Negative succession,--animals die out

Summary. Most of the students enter our nonmajors' biology course viewing ecosystems primarily as large collections of organisms. To the extent that they view those organisms as interacting, they think primarily in terms of interactions involving two species only, especially symbiosis, predation, and parasitism. Although most of our students can identify food chains and trophic levels among producers and consumers, they are prevented by a variety of problems from understanding the major organizing principles of systematic ecology, including matter cycling, energy flow, and succession. These are the critical barriers to learning that this module is designed to help you overcome.

We expect that most students in other high school and college nonmajors' courses will experience difficulties like those of our students. The diagnostic test included as Section II of this module is designed to help you assess which of these problems are shared by your own students.

Using This Module to Overcome Critical Barriers

For many students in a beginning biology course, the naive conceptions described above are deeply ingrained. We have found that for such students even the best explanations are not enough. Replacing easy and familiar ideas with more abstract biological conceptions is a difficult process requiring sustained effort on the part of the student, corrective feedback from teachers, and many opportunities for practice and application.

The materials in this module are ones that we have developed, field-tested, and found to be useful in helping students overcome the critical barriers described above. In addition to lecture materials providing clear explanations of ecological processes (Section III), this module includes a diagnostic test that can be used as both a pretest and a posttest (Section II), a field activity (Section IV), and problem sets (Section V). These materials can be used either independently or in combination, and they do not need to be used in any particular order, although the laboratory activities and problem sets are designed to be done *after* students have read or heard explanations of the relevant concepts. The materials are useful because they help teachers do three things that are essential for helping students to overcome critical barriers:

1. Diagnose student difficulties. The diagnostic test, the laboratory activities, and the problem sets all contain questions designed to reveal how well students understand the biological conceptions of ecology. The commentary for teachers describes specifically what each question is designed to reveal.

2. Create dissatisfaction with naive conceptions. Many students enter our course expecting to memorize facts and definitions when we would like them to think scientifically. The activities in this module provide students with many opportunities to see that their present ways of explaining and predicting scientific phenomena do not work very well and to understand how their ideas need to be changed.

3. Provide opportunities for practice and application. The scientific conceptions described above are important because they explain many different

phenomena in a satisfying way. The activities in this module help students to see the power of these conceptions by applying them to a variety of phenomena. Since the basic purposes of scientific theories are to explain and to predict, we feel that the questions asking students for explanations and predictions are especially important.

In short, the questions and activities in this module are designed as tools to help you, the instructor, help your students through the process of conceptual change. This module cannot substitute for your personal planning and judgment, but it can help make your plans and judgments better informed and thus more effective.

II. Diagnostic Test and Commentary

This student test has been developed and tested over the course of several terms. It is designed to be given as a diagnostic pretest, and/or as a posttest. It should take about 15 minutes for most students to complete. As a pretest, it is designed to help you (a) assess your students' background in subjects critical to an understanding of ecology and (b) become aware of the critical barriers to your students learning when they enter your class. As a posttest it gives you an opportunity to evaluate the success of your teaching.

On the following left-hand pages is the test as we have used it with our students. On the right-hand pages is a commentary explaining the purposes of each question and suggesting how student answers can be interpreted.

Your students' answers will probably be most revealing and useful if students do not take the test for a grade and if you ask them to try to describe how they think about the question even when they do not know the correct scientific answer. The students' incorrect answers to these questions are often more interesting and revealing than their correct ones.

Ecology Test

This test is designed to help us assess how your thinking about ecological problems compares with that of a biologist. Please answer each question as thoroughly as you can. Even if you are not sure of the right answer, try to explain how you think about the problem.

1. A remote island in Lake Superior is uninhabited by humans. The primary mammal populations are white-tailed deer and wolves. It is left undisturbed for many years. Select the best answer(s) below for what will happen to the average populations of the animals over time.

____a. The deer will all die or be killed.
____b. The wolves will all die or be killed.
____c. On the average, there will be a few more deer than wolves.
____d. On the average, there will be a few more wolves than deer.
____e. On the average, there will be many more deer than wolves.
____f. On the average, there will be many more wolves than deer.
____g. On the average, the populations of each will be about equal.
____h. None of these. My answer would be ______________________________

____

____

Reason for your choice:

2. Bacteria and fungi live off dead plants and animals. Assume that our remote island in Lake Superior, with its deer and wolves, somehow was left without any bacteria of fungi whatsoever. Try to describe the ways this would affect the ecosystem as time progresses.

After a year. Reason for your answer.

After 5-10 years or longer. Reason for your answer.

3. Green plants need energy to survive and grow. From the list below, circle the item(s) which you think are used by green plants as source(s) of energy for growth and survival. Explain your answer if necessary.

water soil sunlight fertilizer insects in the soil bacteria

Explain:

Commentary

1. This question focuses on the concept of the energy pyramid. Biologists will recognize that there should be many more deer than wolves because less energy is available to support animals at higher trophic levels. To answer this question acceptably, students should (a) choose option e and (b) give a reason involving comparisons of energy, biomass, or population size at different trophic levels.

2. This question focuses on the role of decomposers in the ecosystem. The best answers to this question should mention the role of bacteria and fungi in recycling needed nutrients. Students who mention the importance of decay or decomposition without mentioning recycling of nutrients probably have an inadequate understanding of matter cycling in ecosystems.

3. This question focuses on the role of plants in energy flow in ecosystems. "Sunlight" is the only correct answer. Students circling other options generally have some of the misconceptions about the nature of energy, energy transformations, or energy flow in ecosystems described in the introduction.

4. A human needs energy to carry out life functions such as breathing, moving or growing.

   a. Which of the following is (are) source(s) of energy for human life functions? (check all correct)

   milk _____, water _____, sugar _____, minerals (e.g., iron in Geritol) _____,

   hamburger _____, oatmeal _____, sunlight striking our skin _____, heat _____.

   b. Select one of the human energy sources above and trace its energy back to its ultimate source, showing all the transitions it may have gone through.

   Humans get energy from ______________________________.

   That energy comes from ________________________,

   which comes from ____________________________,

   which comes from ____________________________, etc.

   What was the ultimate source of the energy in this food? ______________

   Please explain reasons for your answer.

5. Several years ago John Christopher wrote a gripping science fiction book called <u>No Blade of Grass</u>. In it he described the chaos that enveloped the earth when a rapidly spreading deadly virus attacked all forms of grass, including all grains such as wheat, corn, and rice.

   If we were suddenly faced with the destruction of all forms of the grasses, try to predict what would happen to human food supply. Consider the following foods:

eggs	pork chops	white bread	tuna
cabbage	potatoes	cheese	
rice	oranges	roast beef	

   a. Which of these foods would still be available in substantial quantities?

   b. Which of these foods would be scarce or nonexistent. Explain why each food that you list below would become scarce.

4. Like question 2, this question focuses on the concepts of energy and energy flow.

   a. The first part of the question requires students to separate foods which do supply humans with energy from substances low in chemical potential energy (water, minerals) and from forms of energy which we are unable to use (sunlight, heat).

   b. The second part of the question asks students to trace the energy in food back down the food chain and then to sunlight, its ultimate source. We have found that the number of students who are able to do this without losing track of the energy at some point is relatively small.

5. This question was the easiest pretest question for many of our students because it requires reasoning about food chains, a concept with which most of our students are familiar. Expected answers:

   a. Cabbage, potatoes, oranges, and tuna would remain available

   b. Rice and white bread would disappear.

   Eggs, pork chops, cheese, and roast beef would be scarce or nonexistent because they come from animals for whom grasses or grains are important food sources.

6. A farm field in central Michigan is left unplowed after it has been planted to corn year after year. Assume that humans do nothing to the field for another hundred years.

In the chart below predict what kinds of plants and animals yo· ould expect to find in the field.

	Plants	Animals
After 1 year.		
After 10 years.		
After 100 years.		

6. This question is designed to assess students' understanding of succession. We see four general levels of sophistication in students' responses to this question:

   a. A few students depict a process of *negative succession*, in which death and decay gradually come to dominate over life.

   b. Other students describe *arrested succession*, in which they describe the growth of weeds, shrubs, insects and other small animals, but not progression to a climax community (a beech-maple forest in central Michigan).

   c. The most common types of answers describe the gradual growth of trees or return to a "state of nature," but are very vague about both the succession process and its end result.

   d. A few students describe successional trends that are important to ecologists, such as increases in species diversity, stability of the biotic community, or complexity of community organization.

The choice of central Michigan as a location was determined by the location of Michigan State University. You may wish to change this question to reflect your own location.

III. Materials for Lecture or Discussion

This section contains a series of copy-ready masters for overhead transparencies that may be used as lecture supplements or as a basis for discussion in lecture or recitation sessions. Transparencies A through D are designed to be used sequentially; each succeeding transparency addresses energy flow and matter cycling in a slightly more complex and sophisticated manner.

Each transparency is designed to address one or more key concepts and/or to confront important critical barriers. They are found in copy-ready form on the left-hand page, with commentary explaining the purpose of the transparency on the opposing page.

Contents

A. Matter and Energy--overhead transparency (page 14)
B. Energy Flows and Matter Cycles--overhead transparency (page 15)
C. Food Webs and Trophics Levels--overhead transparency (page 16)
D. Food and Energy Pyramids--overhead transparency (page 17)
E. Carbon Cycle and Nitrogen Cycle--overhead transparency (page 18)
F. Succession in Mid-Michigan--overhead transparency (page 19)

Matter and Energy

Matter

-Is the "stuff" that the universe is made of.

-Changes form, but is never created or destroyed in biological systems (Conservation of Matter).

-Consists of atoms that are bound together to form molecules.

-Atoms are never created or destroyed in biological systems, but molecules can be.

Energy

-Is whatever changes matter or moves it around.

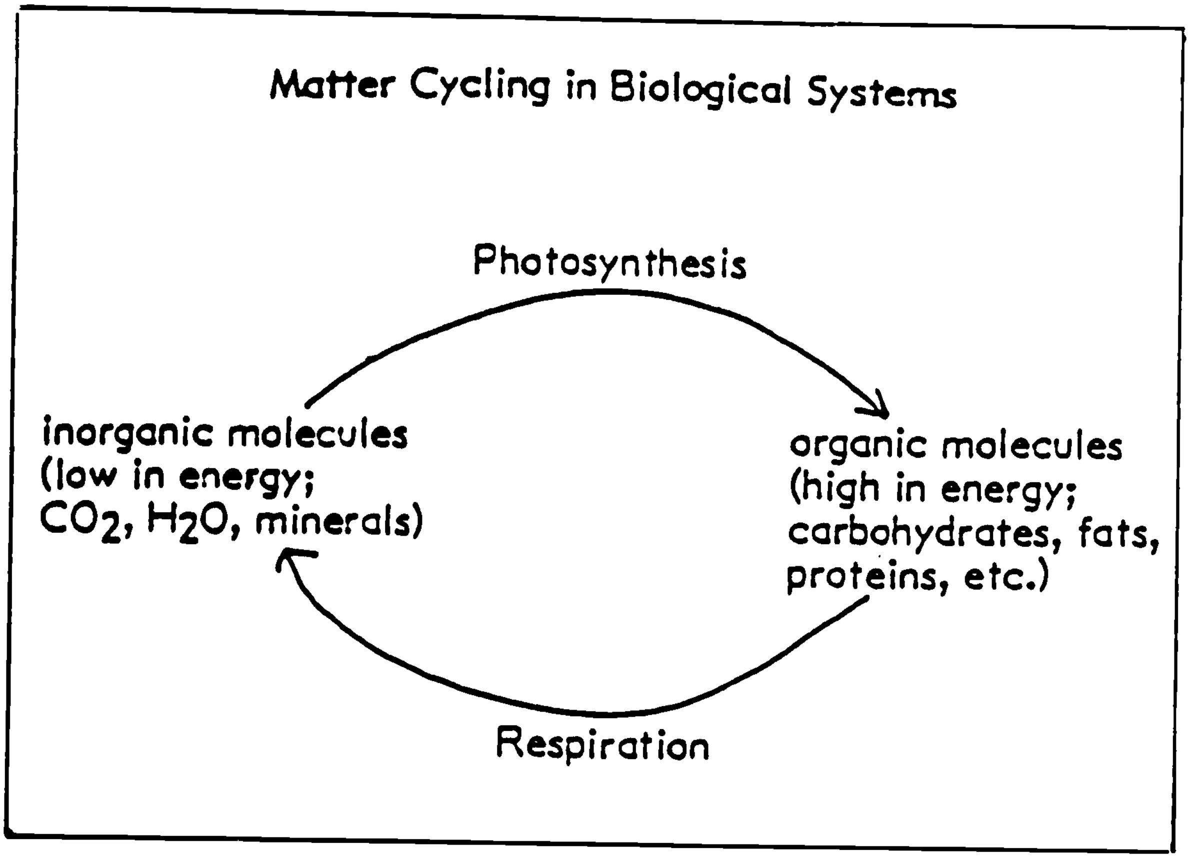
-Changes form, but is never created or destroyed in biological systems (Conservation of Energy).

-Has many forms, including light, heat, and motion.

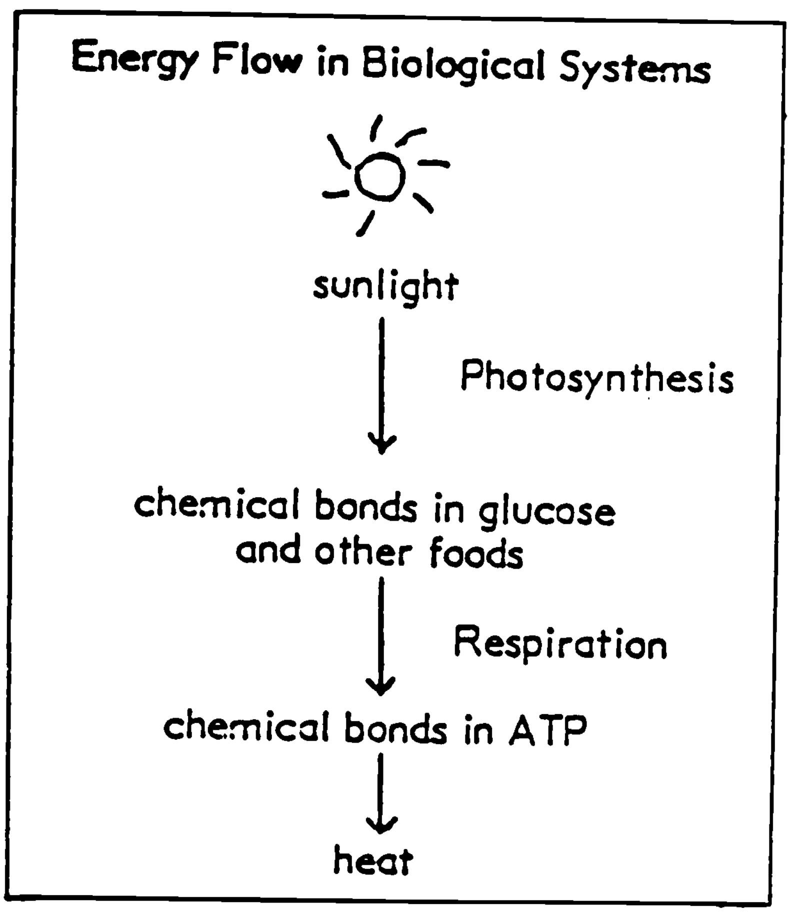
-Can be stored in certain molecules (chemical potential energy) and released when chemical bonds are broken.

A. Matter and Energy

This transparency is designed to address students' difficulties in understanding the nature of matter and energy. It defines each in very simpl terms, states the conservation laws, and describes a few properties of each that must be understood to follow energy flow and matter cycling. The degree of understanding engendered by this transparency is obviously minimal, but these points are essential if any discussion of energy flow and matter cyclin is to make sense to the students.



Matter Cycling in Biological Systems



Energy Flow in Biological Systems

B. Energy Flows and Matter Cycles

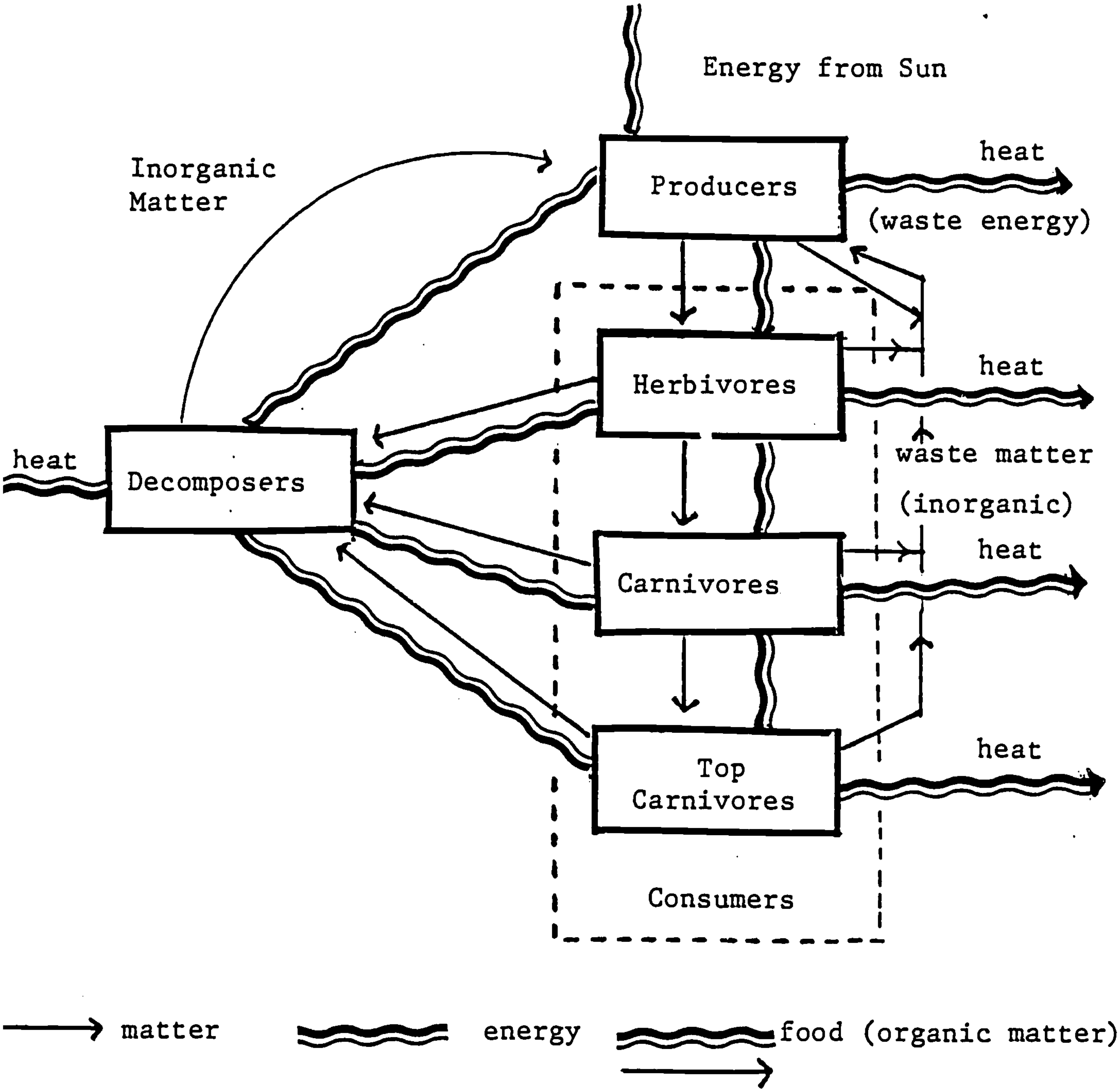
This transparency depicts matter cycling and energy flow in the simplest possible terms, simply making the point that the two systems occur in ecosystems. For discussing this transparency, you may want to describe where and when these conversion processes occur:

1. Energy in sunlight is converted to chemical potential energy in food through photosynthesis. This occurs only in producers.

2. Chemical potential energy in food is converted to chemical potential energy in ATP through respiration. This occurs in all organisms.

3. Photosynthesis and respiration also play important roles in matter cycles, converting matter from organic to inorganic forms and back again.

FOOD WEBS AND TROPHIC LEVELS



Energy <u>flows</u> through the ecosystem

Matter <u>cycles</u> within the ecosystem

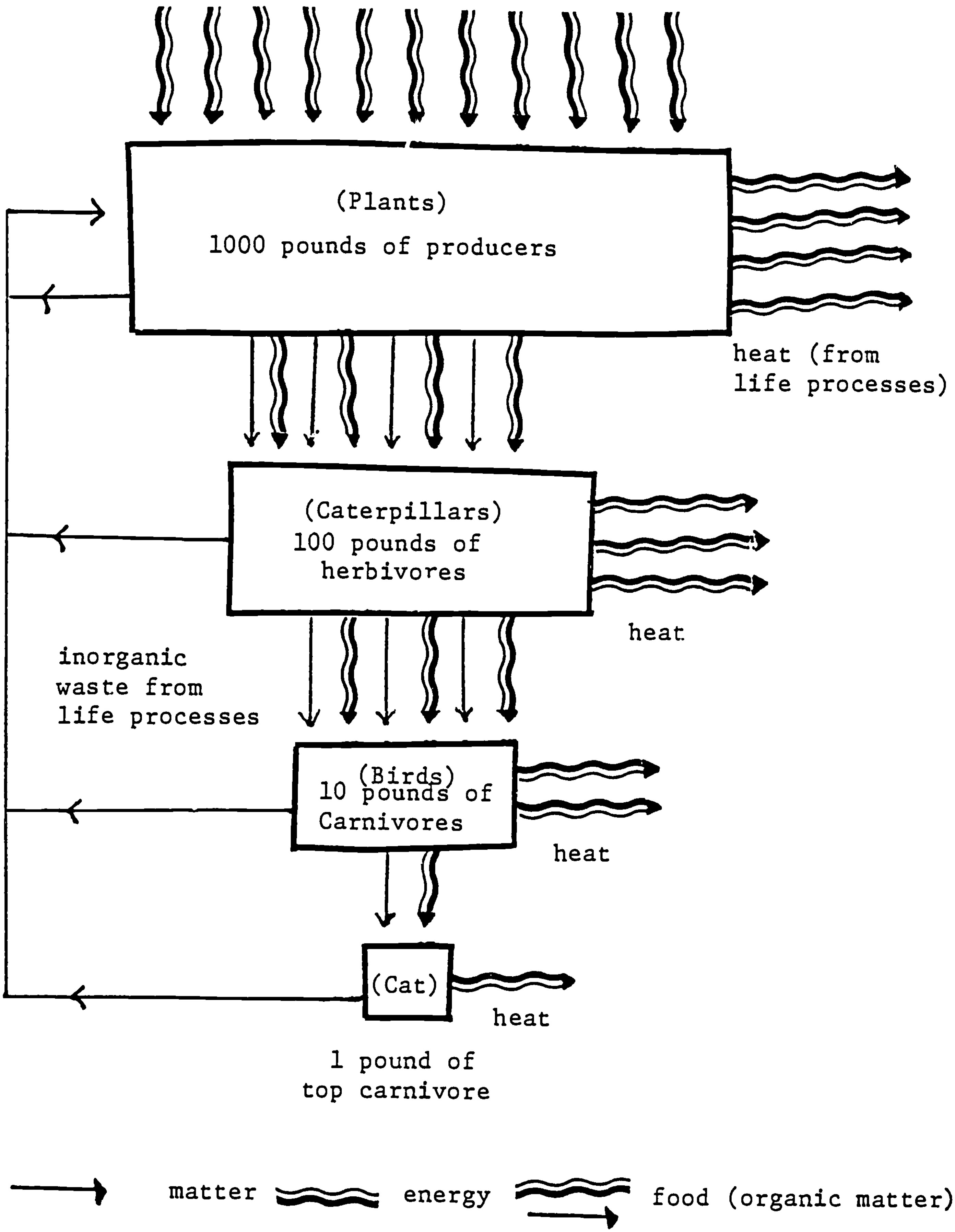
C. Food Webs and Trophic Levels

This transparency combines the ideas of energy flow and matter cycling, depicted separately in the previous transparency, and places them within the context of the structure of an ecosystem. The result is a complex pattern that most students will need to study and discuss at some length. We recommend that you guide them through energy flow (wavy lines) and matter cycles (straight lines) separately, pointing out that

1. Both energy flow and matter cycling have a variety of branches or alternate paths.

2. Because food is a source of both matter and energy, both are transferred together through the food chain. However, energy and matter follow very different paths into and out of the abiotic environment.

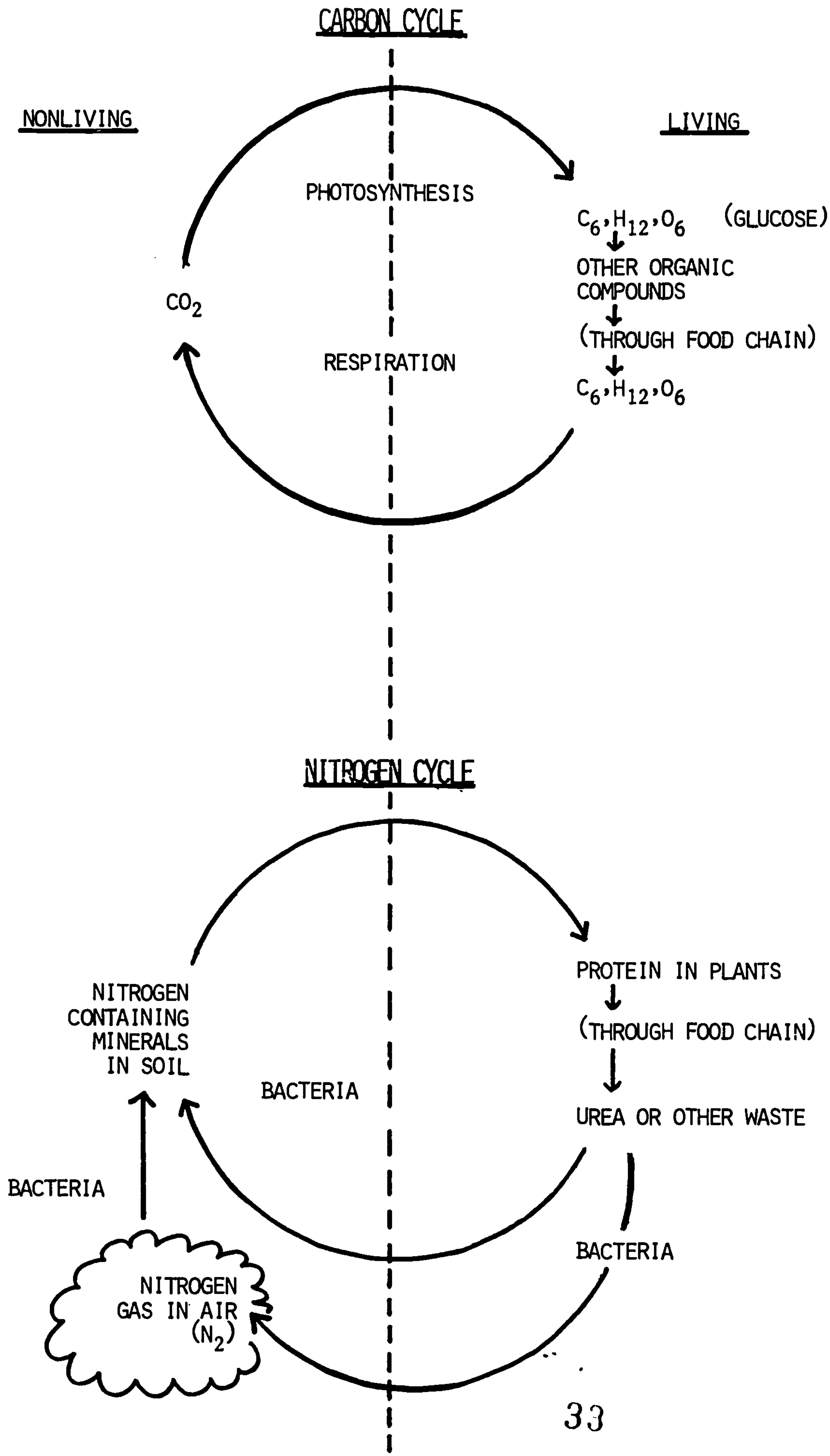
FOOD AND ENERGY PYRAMIDS



D. Food and Energy Pyramids

This transparency is in many ways similar to the previous one. It differs (a) in that decomposers have been eliminated, and (b) in that energy and matter transfer processes have been treated in a semiquantitative manner: Because some energy and matter is used to satisfy metabolic needs at each trophic level, only a portion of the gross production can be passed on to the next level. (Note that the numbers of pounds at each trophic level refer to production, not to biomass of the population.)

The treatment is only semiquantitative in that it follows the "10% rule": About 10% of the production at one trophic level is transformed into production at the next. The actual percentage varies widely depending on the ecosystem and the organisms involved.


CARBON CYCLE
NONLIVING
LIVING
PHOTOSYNTHESIS
C_6,H_{12},O_6 (GLUCOSE)
OTHER ORGANIC COMPOUNDS
(THROUGH FOOD CHAIN)
C_6,H_{12},O_6
CO_2
RESPIRATION
NITROGEN CYCLE
PROTEIN IN PLANTS
(THROUGH FOOD CHAIN)
UREA OR OTHER WASTE
NITROGEN CONTAINING MINERALS IN SOIL
BACTERIA
BACTERIA
BACTERIA
NITROGEN GAS IN AIR (N_2)

E. Carbon Cycle and Nitrogen Cycle

Note. This transparency assumes far more chemical knowledge than most students have when they enter our course or than is developed in this module.

The transparency depicts the carbon and nitrogen cycles in extremely simplified form, with an emphasis on the portions of the cycles of which our students are least aware, particularly the ways in which carbon and nitrogen move from the abiotic environment to the biotic community and back.

SUCCESSION IN MID-MICHIGAN

DOMINANT PLANT SPECIES:

1. Plowed field
2. Weeds and small shrubs (pioneer species)
3. Shade-intolerant trees (e.g., cottonwood)
4. Moderately shade-tolerant trees (e.g., oak, hickory)
5. Shade-tolerant trees (e.g., beech, maple) This is the climax community.

IMPORTANT CHARACTERISTICS OF SUCCESSION:

1. Different animals and other organisms are associated with each plant community
2. Early populations go through boom-and-crash cycles. Each population prepares the ecosystem for later stages.
3. The climax community
   (a) has the greatest biomass
   (b) captures the sun's energy most efficiently (or nearly so)
   (c) has stable populations
   (d) has stable nutrient cycles

F. Succession in Mid-Michigan

Note. This transparency is clearly designed for our location. You may well want to design your own version for your area.

This transparency describes the process of succession, pointing out essential stages and characteristics of the process and helping students to see how the complex structures of the mature community develop gradually over time.

IV. Field Activity: Succession Field Trip

Ecology is a field science, and much of the attraction of ecology comes from being in the field and from seeing how ecological principles can be used to develop a systematic understanding of a rich, variable natural community. We therefore recommend that you include a field trip to a natural site in your teaching about ecology. Some guidelines that you may find useful are presented below.

The Site

1. Should be close enough to classroom to allow for more than one trip if possible.

2. Should show two or more seres in relationship to one another with an edge or ecotone showing transitions, for example, old field to forest or open water to dry land.

3. Should allow for locating pioneer plant species as well as succeeding species of other successional seres.

Alternatives to a Successional Site Nearby

1. An instructor-made slide set showing succession
2. An all-day field trip to a likely site away from classroom
3. Appropriate films or film strips
4. Other

Key Points of a Successional Field Trip

1. Note current status of site: vegetation--location, type, height; animal life--evidence of insects, reptiles, birds, mammals.

   Influence of humans: building a foundation, fence rows, effects of tillage or grading, and so forth.

2. Locate vegetation types that represent the sere. Identify, if possible.

3. Locate vegetation types that indicate the future of the sere (e.g., intrusion of shrubs into old field, or trees). Identify, if possible.

4. If the site comprises two seres with an ecotone, note the transitional aspects of this region, citing the diversity of species found there.

5. In sites such as old fields, locate the pioneer species, noting the rapid growth and high reproduction capacity of early plant stages, rapid turnover of matter, and high energy use and production.

6. In climax forest, note size of trees and the amount of matter locked up for long periods of time in the plant.

Also note effects of tree removal to the immediate site: light to forest floor, rainfall, change in successional sequence in the gap area.

7. Locate decomposers or evidence of decomposition--matter cycles.

Suggested Activities on Site

1. Conduct guided tour with instructor lecturing.

2. Use M^2 plot survey for locating species density.

3. Use transect survey for locating species diversity.

4. Make a sweep looking for insects, noting species diversity and herbivory.

5. Make a key for significant plants on site.

V. Problem Sets

The following section includes questions on ecology organized into two problem sets. The questions give students a chance to use newly acquired scientific conceptions to solve problems. Also, you can evaluate student responses to assess how well students have replaced naive conceptions with scientific conceptions.

Problem Set 1 focuses on energy flow, matter cycling, and succession. Problem Set 2 focuses on the detailed organization of ecosystems, the concepts of niche and habitat. Both problem sets can be done by students independently, then checked by the instructor and/or discussed in class. The problems can also be adapted for use as test questions.

These problems are difficult for students because they require students to organize their newly acquired knowledge into a coherent scheme. Many students will need to discuss the questions in class after attempting to answer them.

Problem Set 1: Energy Flow, Matter Cycles, and Succession

1. a. In any given community organisms can be classified as producers, consumers and decomposers. Classify each of the organisms listed below as producers (P), consumers (C), or decomposers (D).

_______grass (blades & seeds)

_______soil bacteria

_______mushroom

_______earthworm

_______coyote

_______mosquito

_______bat

_______hawk

_______mouse

_______deer

_______white cedar

_______frog

_______purple martin

b. Assume that the organisms listed above live together in a biological community. Show how energy flows through that community in the space below. Start with sunlight and end with heat; try to include every organism in your diagram.

Commentary

1. a. The first part of this question asks students to classify organisms as producers, consumers, or decomposers. We anticipate that most students will accurately identify the producers and consumers, but some may have difficulties with the decomposers: soil bacteria, mushroom, earthworm.

b. The second part of the question basically asks students to construct a food web; the wording of the question emphasizes the importance of the *energy* passed from one organism to another in the food web.

2. A succession is a change in plant and animal communities over time in the same area. Imagine what this campus looked like when the first white settlers reached this region. Try to find evidence of the kind of vegetation that was here before massive human intervention occurred. (Can you find any plants that were here before white settlers arrived?)

   a. What would that vegetation be?

   b. Have humans intervened and changed the succession? In what ways?

   c. Assume that all the humans left this area today, never to return. What changes do you think would occur in the vegetation and the animal life over the next 20 years? The next 100 years? The next 500 years?

3. Matter cycles throughout the ecosystem. One of the crucial building blocks of all living tissue is carbon. All organic matter consists of carbon, hydrogen, and oxygen and other elements in a great variety of compounds.

   Trace the path a carbon atom could take as it cycles from the abiotic to the biotic and back to the abiotic parts of the ecosystem. Include at least 5 different locations where the carbon atom resides at one time or another during the cycle. Label the parts of your cycle.

2. This question focuses on succession and the concept of a climax community. Students are encouraged to think about how we have affected the community in our area, and what would happen to the community if we left.

3. This question asks students to follow a carbon atom through a matter cycle. The question is easy for students who understand the roles of photosynthesis, respiration, and food chains in the carbon cycle. If students are having difficulty with any of those concepts, their difficulties will be revealed by this question.

Problem Set 2: Habitats and Niches

1. Biologists often use an analogy to say that an organism's habitat is its "address" and its niche is its "profession or job." A habitat provides the basic needs of an organism: food, inorganic matter, an opportunity to reproduce, and so forth. Each organism has special requirements which are variables of these basic generic items; these special requirements of each species define its niche.

   Different species do not occupy the same niche at the same time. In other words, organisms that have very similar requirements will not maintain populations at the same "address," for one or the other will be able to be more successful and survive while the other will not. Biologists think that niches cannot be identical, even if they are very similar. To understand a particular niche filled by a particular organism, one must know a lot of specifics about the habitat and the habits of the organism. Wildlife biologists and ornithologists (who study birds), tend to use the niche concept more extensively than do botanists or foresters, possibly because the concept is more workable in some disciplines than others.

   The ruby-throated hummingbird feeds on ants, beetles, flies, spiders, nectar. Emergency feeding of sugar water or honey water in a crisis may help hummingbirds get through times when they arrive here before insects or nectar are readily available. In general, artificial food sources (hummingbird feeders) should not be used extensively.

   a. Describe the <u>niche</u> you think hummingbirds occupy in an ecosystem.

   b. How does the presence of hummingbirds affect:

      flowering plants that supply nectar?

      ants?

      spiders?

      plants that ants feed on?

      insects that spiders feed on?

1. This question describes the concepts of habitat and niche, then asks students to apply those concepts to the ruby-throated hummingbird. These concepts are important because they emphasize that each species plays a specific role in the structure and function of the ecosystem as a whole. The hummingbird's niche must be defined by its *relationship* to other plants and animals in the community, not simply by some set of qualities of the hummingbird itself.

2. Bronzed grackles and robins both selected nest sites in a 20- to 25-year-old ornamental spruce plantation in a suburban back yard. When the trees were younger, robins successfully rested there, along with mourning doves, and an occasional catbird (in adjacent shrubbery). The grackles moved in, began nesting in the spruce trees, and defended their nests against birds and pets of the homeowner. The robins did not nest in the area for 4 or 5 years then a pair returned. One year there was a spruce "apartment house" arrangement, with grackles nesting in the upper parts of one tree and the robins in the same tree but at a lower level. The mourning doves have continued to nest in the spruce trees all along.

   Now the robins have returned to be frequent nesters in the spruce, and the grackles have moved out.

   Robins and grackles can be seen feeding on earthworms, caterpillars, beetles, crickets, and other animal foods as well as a variety of fruits and seed coverings throughout the year. Both species migrate to warmer climates during the winter months. Both species use twigs, mud, grass as nest building materials.

   a. Describe the habitat conducive to mourning doves, robins and grackles.

   b. What niche do both grackles and robins fill?

   c. Why do you think the grackles chased the robins out for a time?

   d. What probable factors permitted robins to return to the back yard, whereas the grackles moved away?

   e. What evidence do you have that the mourning doves' niche does not interfere with the grackles or the robins?

2. This question describes a situation in which two species of birds are each capable of filling the same niche, but the nature of ecological relationships prevents this from actually occurring. The questions ask students to use the concepts of habitat and niche to interpret the sequence of events.